Effects of Cumulus Convection on Rapidly Intensifying Cyclones

M.K. Yau
Department of Atmospheric and Oceanic Sciences
McGill University
805 Sherbrooke St. West
Montreal, Canada H3A 2K6
Phone: (514)398-3719
Fax: (514)398-6115
E-Mail: yau@rainband.meteo.mcgill.ca

R.R. Rogers
Department of Atmospheric and Oceanic Sciences
McGill University
805 Sherbrooke St. West
Montreal, Canada H3A 2K6
Phone: (514)398-3719
Fax: (514)398-6115
E-Mail: rogers@zephyr.meteo.mcgill.ca

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LONG-TERM GOAL

To explain the interactions between convective processes and larger scale marine weather systems, to increase our understanding of the processes affecting the size distribution of cloud droplets in maritime clouds, and to study atmospheric processes through application of new methods of remote sensing.

OBJECTIVES

To investigate the effects of convection and cloud microphysics on rapidly intensifying oceanic cyclones. To determine how mixing affects cloud dropsize distribution in the presence of wind shear. To examine whether microscopic supersaturation can broaden cloud dropsize spectra. To explore how longwave cooling affects cloud dynamics and microphysics in trade-wind cumulus clouds. To analyze the structure of a simulated hurricane. To develop methods for measuring the buoyancy flux in the boundary layer using wind profiler and RASS data.

APPROACH

Theoretical and modeling studies using a hierarchy of models. Observational studies of weather events to support modeling activities.

WORK COMPLETED

The development of explicit microphysics in a compressible mesoscale model and simulation of the ERICA IOP2 storm. The analysis of the relation between mixing and cloud dropsize distribution in a

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two-dimensional cloud model. A study on the interaction between longwave radiation and cloud dynamics in a small convective cloud. A triply-nested grid simulation of Hurricane Andrew. An analysis of the kinematic structures and inner-core characteristics of the simulated Hurricane Andrew. An examination of the surface winds during the landfall of a hurricane. A direct numerical simulation study on the growth of cloud droplets in a turbulent flow. Development of a method for measuring the heat fluxes in a convective boundary layer using a Radio-Acoustic Sounding System (RASS).

RESULTS

(1) We developed an explicit microphysics scheme in a mesoscale model and used it to simulate the development of the ERICA IOP2 storm. The scheme captures well the deepening rates, the structures on the mesoscale, and the distribution of cloud and precipitation as verified against observations (Kong and Yau, 1997). (2) We compared the modeled cloud droplet spectra in the upshear side and the downshear side of a small cumulus cloud. We showed that the size distributions of cloud particles are similar between the upshear and downshear sides of individual cloud turrets provided that they are composed of cloudy air of rather uniform age. However, there are important differences in the spectral properties between new cloudy air growing on the upshear side of the cloud and older cloudy volumes dissipating on the downshear side (Vaillancourt, Yau, and Grabowski 1997). (3) We explored the interaction between radiation and the microphysics and dynamics of clouds (Guan, Yau, and Davies 1997). For a small cumulus, we found that longwave radiative cooling increases significantly the maximum cloud water content. In particular, cooling from radiation and evaporation of cloud water enhanced the downward motion along the cloud edges. This in turn strengthens the low-level convergence to promote further cloud development. (4) We examined the effect of the non-uniform spatial distribution of cloud particles on the condensational growth of a cloud droplet. We simulated the motion of thousands of droplets in a turbulent flow (Vaillancourt, Yau, and Grabowski 1998) and demonstrated that in the absence of turbulence or sedimentation of particles, the non-uniform spatial distribution of droplets produces significant broadening of the size distribution. However, the broadening becomes quite small when turbulence and sedimentation effects are included. (5) We developed a technique of estimating heat fluxes in the boundary layer from a Radio-Acoustic Sounding System, RASS (Potvin 1998). (6) We simulated Hurricane Andrew (1992) using the Pennsylvania State University/National Center for Atmospheric Research (PSU/NCAR) nonhydrostatic mesoscale model (MM5). The simulation produces many features of the storm which compare well with observations (Liu, Zhang, and Yau 1997). (7) We analyzed the details of the air motion and the thermodynamic structures in the simulated storm and proposed a conceptual model of the airflow in an intense hurricane (Liu, Zhang, and Yau 1998). (8) We showed that the surface winds in the simulated Andrew agree with observations and that horizontal advection of momentum can smooth out the wind discontinuity downstream from the coastline during the landfall of a hurricane (Zhang, Liu, and Yau 1998).

PUBLICATIONS

Journal publication

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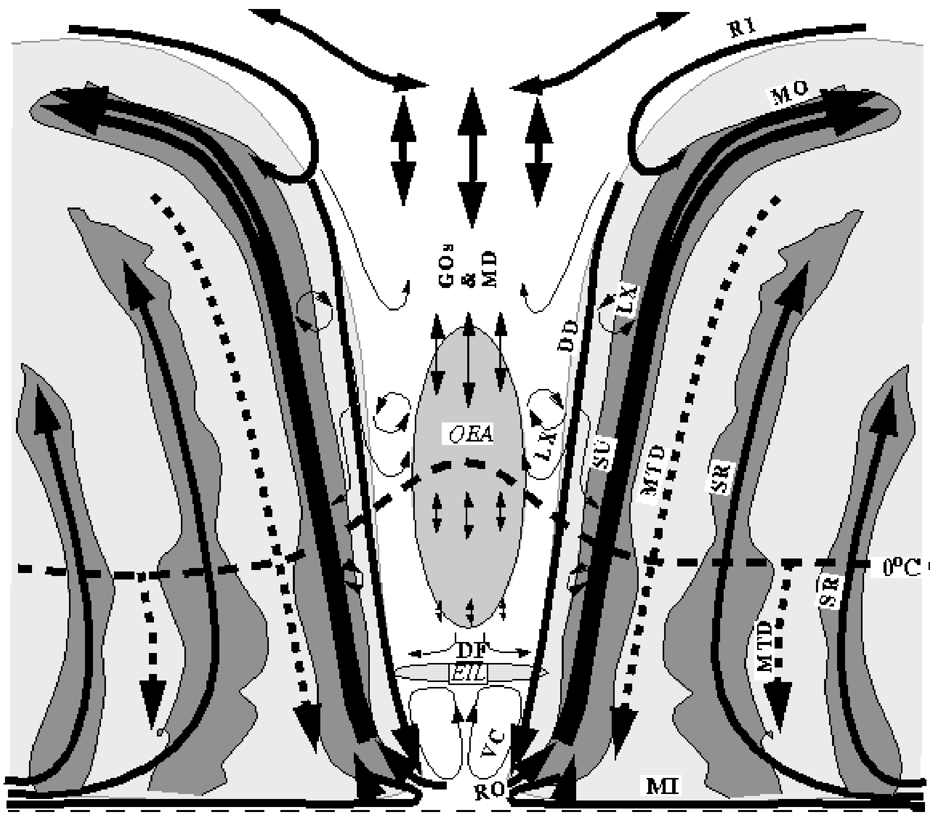

A conceptual model of a mature hurricane in the inner core region. The light shaded areas denote regions with cloud and precipitation. The dark shaded areas depict the convective eyewall and spiral rainbands. The medium shaded areas denotes the inversion layer in the eye (EIL) and the occluded air in the eye(OEA) respectively. The freezing level is marked by a dashed line. The meaning of the other symbols are:

- ***MI - Main Inflow; MO - Main Outflow; SU - Sloping Updraft;***
- ***RO - Return Outflow; RI - Returning Inflow; MTD -Moist downdraft;***
- ***SR - Spiral Rainband; DD - Dry Downdraft; LX - Lateral Mixing;***
- ***GOs - Gravitational Oscillations; MD - Mean Descent in eye;***
- ***DF - Divergent Flow in inversion; and VC - Vertical Circulation below inversion.***